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THE EFFECT OF AFRICAN LEAF TEA ON CHANGES IN HEMATOCRIT AND BLOOD PRESSURE

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ABSTRACT
Hypertension is a non-communicable disease that often presents without symptoms and is one of the leading causes of death worldwide. The prevalence of hypertension is significantly higher in women compared to men. Among women of childbearing age, hypertension increases the risk of complications during pregnancy, such as preeclampsia and bleeding. Elevated hematocrit levels are strongly associated with hypertension in women, contributing to increased vascular resistance and blood pressure. Efforts to manage hypertension include pharmacological and non-pharmacological therapies. In North Maluku, one of the traditional healing practices passed down through generations for lowering blood pressure involves the use of African leaves (Vernonia amygdalina). This study aims to analyze changes in hematocrit levels and blood pressure in women of childbearing age with hypertension before and after consuming 2.4 grams of African leaf tea (Vernonia amygdalina) for 14 days as a companion to antihypertensive medicine. This research employed a true experimental design with a pretest-posttest control group format. The population consisted of 97 hypertensive women of childbearing age in the service area of the Sanana Public Health Center, Sula Islands, North Maluku. A total of 32 participants were randomly selected. The intervention group received Amlodipine 5 mg as an antihypertensive medication along with 2.4 grams of African leaf tea consumed once daily for 14 days. Blood pressure measurements and venous blood sampling for hematocrit level analysis were conducted on days 8 and 15. Data were analyzed using the General Linear Model Repeated Measures (GLM-RM) approach. The findings demonstrated significant reductions in hematocrit levels and blood pressure among hypertensive women of childbearing age in the intervention group, with a p-value of 0.000. The administration of 2.4 grams of African leaf tea (Vernonia amygdalina) daily for 14 days, as a complementary therapy to antihypertensive medication, is effective in reducing hematocrit levels and blood pressure in women of childbearing age with hypertension.

Keywords: african leaves; hematocrit levels; hypertension; reproductive age women

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INTRODUCTION

Hypertension, commonly referred to as a "silent killer", is a non-communicable disease that often progresses without symptoms but can result in severe complications over time, including stroke, kidney failure, and heart disease (Cholifah, 2022). Hypertension is clinically defined as a systolic blood pressure of ≥ 140 mmHg or a diastolic blood pressure of ≥ 90mmHg (Kemenkes, 2021). Women of childbearing age with hypertension face an increased risk of preeclampsia and bleeding during pregnancy, with studies indicating they are 4.125 times more likely to develop preeclampsia (Herawati, 2021). Globally, the prevalence of hypertension is significant, with the World Health Organization (WHO) reporting that 22% of the world's population was affected in 2019 (Ester, 2021). The prevalence is highest in Africa, where 46% of the population, including 80 million adults in Sub-Saharan Africa suffer from hypertension (Puskesmas Tenggarang, 2022). Southeast Asia ranks third, with a prevalence of 25%. In Indonesia, the 2023 Indonesian Health Survey (SKI, 2023) reported a hypertension prevalence of 29.2%, with rates increasing significantly with age: 10.7% among individuals aged 18–24 years, 17.4% for ages 25–34, 27.2% for ages 35–44, 39.1% for ages

45–54, 49.5% for ages 55–64, 57.8% for ages 65–74, and 64% for those over 75 years old (BPS, 2018).

Hypertension is a non-communicable disease and a significant contributor to premature mortality worldwide. The prevalence of associated risk factors, including obesity, high blood pressure and diabetes, is notably higher among women compared to men. Hypertension can affect individuals of all ages and demographics; however, women of childbearing age (WUS) are particularly vulnerable. Women of childbearing age, defined as those between15 and 49 years old, encompass individuals in their reproductive years, whether they are married, widowed or planning to start a family (Herawati, 2021). Efforts to reduce blood pressure have involved both pharmacological and non-pharmacological therapies. Pharmacologically, hypertension can be managed with medications such as Amlodipine, which is administered orally at a dose of 5mg once daily (Herawati, 2021). Non-pharmacological approaches often incorporate the use of medicinal plants rich in bioactive compounds, such as flavonoids, known for their potential antihypertensive properties. One such medicinal plant is the African leaves (*Vernonia amygdalina*), a shrub native to the African continent that thrives in tropical climates, including regions of Indonesia. African leaves are commonly found in various natural settings, such as residential yards, riverbanks, forest edges, and grasslands (Kamaluddin & Tamrin, 2023).

Several studies have investigated the effects of African leaves (*Vernonia amygdalina*) on experimental models of hypertension. Research conducted on hypertensive male white rats demonstrated that variations in the dosage of African leaf ethanol tea and the duration of administration significantly influenced reductions in systolic and diastolic blood pressure, with a p-value <0.05. The most substantial decrease in blood pressure was observed in the test group administered a dose of 800mg/kg body weight on the 15th day of examination (Hanafi, 2021). Research on the use of African leaves (*Vernonia amygdalina*) in human subjects has primarily focused on hypercholesterolemia, with limited studies addressing their efficacy in hypertensive patients, particularly in the form of a decoction suitable for women of childbearing age. Prior studies have revealed that 100g of African leaves *(Vernonia amygdalina)* contain various nutrients, including protein, fiber, carbohydrates, fat, ascorbic acid, carotenoids, calcium, iron and chemical compounds including flavonoids, alkaloids, saponins, terpenoids, tannins, glycosides, alkaloids, indole, anthraquinone and luteolin (Sukmawati et al., 2017). The flavonoid compounds in African leaves play a key role in vasodilation, aiding in the relaxation and dilation of blood vessels. The alkaloid content further contributes by alleviating vascular blockages, making African leaves a potential candidate for lowering blood pressure (Wahyu & Komala, 2020). Flavonoids also exhibit diuretic properties and inhibit the activity of Angiotensin I Converting Enzyme (ACE), which plays an important role in the formation of Angiotensin II, a major factor in hypertension (Dafriani, 2019). Phytochemical screening of a 70% ethanol extract of African confirmed the presence of flavonoids, alkaloids, saponins, tannin quinones, and steroids. Toxicological evaluations have indicated that African leaves are well-tolerated in animal studies, falling within the category of "practically non-toxic" when administered orally to mice (Meidiawati et al., 2018).

The higher the percentage of hematocrit levels, the thicker the blood in hypertensive patients who show elevated hematocrit levels (Sendiang et al., 2022). Hematocrit values are significantly higher in women with hypertension compared to those with normal blood pressure. Increased hematocrit values are associated with higher blood viscosity, which determines blood vessel resistance and contributes to increased blood pressure (Jeong et al.,

2021). A similar study was conducted in North Maluku Province, focusing on the use of traditional medicinal plants and the identification of plant parts used in non-pharmacological therapy, as well as various methods of using them. The results showed that 29 types of medicinal plants were used as non-pharmacological therapy, with leaves being the most commonly used plant part (58.82%). The methods of use included boiling, pounding, and soaking (Kamaluddin & Tamrin, 2023). The use of medicinal plants has significantly developed over time; however, further research and identification are needed to explore plants that have potential as non-pharmacological treatments. If people use these plants without considering the proper dosage, the results may be less effective.

African leaf tea bags (*Vernonia amygdalina)* are made by oven and sun drying, with the oven drying method proving to be the best preparation method. Based on the organoleptic test, the percentage of drying loss is less than 10%, which is in accordance with the standard water content for simplicia. The organoleptic test observations showed that the samples dried using the oven method had a darker green color, a ginger aroma, a bitter taste, and a coarse powder form (Novitasari et al., 2018). According to the Indonesian Health Survey, the prevalence of hypertension in North Maluku, based on measurement results in 2023, was 20.8%. Regarding adherence to antihypertensive medication, 36.7% of sufferers did not routinely take antihypertensive drugs, and 13.7% did not take antihypertensive drugs at all (BPS, 2018). Hypertension ranks first among the ten most common diseases reported by patients in the Sula Islands, North Maluku Province. The community in North Maluku has empirically used African leaves *(Vernonia amygdalina*) to treat high blood pressure, diabetes, and promote wound healing. Recently, there has been increased awareness in the community regarding the functional role of African leaves in managing hypertension, largely due to their flavonoid content (Kamaluddin & Tamrin, 2023). This study aims to analyze the changes in systolic and diastolic blood pressure as well as hematocrit levels before and after consuming African leaf tea *(Vernonia amygdalina)* at a dosage of 2.4 grams daily for 14 days. The research compares outcomes between an intervention group receiving African leaf tea alongside antihypertensive medication and a control group that follows standard antihypertensive therapy alone. Through this analysis, the study seeks to explore the potential of African leaf tea as a complementary therapy in hypertension management.

METHOD

This study employed a true experimental design with a pretest-posttest control group methodology to evaluate the effects of African leaf tea *(Vernonia amygdalina*) on hypertension management. The population consisted of all women of childbearing age with hypertension residing within the service area of the Sanana Public Health Center, Sula Islands, North Maluku, totaling 97 individuals. From this population, a sample of 32 women was selected using a random sampling technique. Participants were divided into two groups: the intervention group and the control group. The intervention group received a combination of 5 mg of Amlodipine daily and 2.4 grams of African leaf tea *(Vernonia amygdalina)* once daily in the morning for 14 days. The control group received only 5 mg of Amlodipine daily for the same duration. Blood pressure measurements and venous blood sampling for hematocrit level analysis were conducted for both groups on the 8th and 15th days of the intervention. Random assignment ensured an unbiased distribution of participants between the intervention and control groups. This study was approved by the Health Research Ethics Committee of the Ministry of Health Polytechnic of Semarang, with ethics approval reference number 1065/EA/KEPK/2024. The collected data were analyzed using the General Linear Model Repeated Measures (GLM-RM) approach to evaluate changes in systolic and diastolic blood pressure, as well as hematocrit levels over time. This statistical method accommodates

repeated measurements within participants, allowing for the examination of differences between the intervention and control groups across multiple time points. Statistical analysis was performed using SPSS version 24, with results interpreted to determine the efficacy of African leaf tea as a complementary treatment for hypertension in women of childbearing age.

RESULT

This study was conducted in July-August 2024 in the working area of the Sanana Health Center, which includes 6 villages: Mangon, Fagudu, Falahu, Waibau, Fatce and Fogi. The Sanana Health Center is located in Mangon Village, Sanana District, Sula Islands Regency, North Maluku Province.

Table 1.
Systolic Blood Pressure Values in the Intervention Group and Control Group based on Measurement Time

Measurement Time	Intervention Group		Control Group	
	Mean Difference	*p value* [a]	*Mean Difference*	*p value* [a]
Pre >< Post 1	12,25	0,000	1,50	0,000
Pre >< Post 2	17,19	0,000	3,25	0,000
Post 1 >< Post 2	4,93	0,000	4,75	0,000

[a] : *General Linear Model Repeated Measures*

Table 1 shows the average decrease in systolic blood pressure pre-test and post-test with a p-value of 0.000 in both the intervention and the control group, indicating significant difference in the average decrease in systolic blood pressure before and after treatment in both groups. The average systolic blood pressure from pretest to post-test in the intervention group decreased by 17.19 mmHg, while in the control group it decreased by 3.25 mmHg. The difference in the average decrease in systolic blood pressure between the two groups is 13.93 mmHg. This indicates that administering 2.4 grams of African leaf tea (*Vernonia amygdalina*) for 14 days as a supplement to antihypertensive medication is more effective in lowering systolic blood pressure than administering antihypertensive medication alone in women of childbearing age with hypertension.

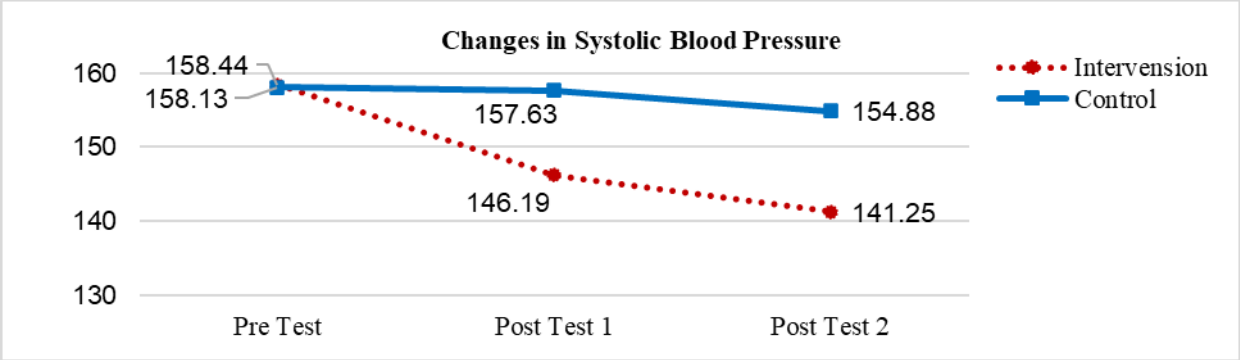

Figure 1. Changes in Systolic Blood Pressure in the Intervention Group and Control Group

The results of the analysis in figure 1 show the average pretest systolic blood pressure in the intervention group was 158.44 mmHg, which decrease after 14 days of receiving 2.4 grams of African leaf tea (*Vernonia amygdalina*), with a difference of 17.19 mmHg between pre-test and post-test values, resulting in a post-test value of 141.25 mmHg. The analysis of the average systolic blood pressure in the control group also showed a decrease, with a pre-test value of 158.13 mmHg and a post-test value of 154.88 mmHg, resulting in a difference of only 3.25 mmHg.

Table 2.
Diastolic Blood Pressure Values in the Intervention Group and Control Group based on Measurement Time

Measurement Time	Intervention Group		Control Group	
	Mean Difference	*p value* [a]	Mean perbedaan	*Mean Difference*
Pre >< Post 1	2,56	0,000	1,12	0,000
Pre >< Post 2	7,31	0,000	4,31	0,000
Post 1 >< Post 2	4,75	0,000	3,18	0,000

[a] : *General Linear Model Repeated Measures*

Table 2 shows the average decrease in diastolic blood pressure from pretest to post-test, with a p-value of 0.000, indicating a significant difference in the average decrease in diastolic blood pressure before and after treatment in the intervention group. The average diastolic blood pressure from pretest to post-test in the intervention group decreased by 7.31 mmHg, while in the control group it decreased by only 4.32 mmHg. The difference in the average decrease in diastolic blood pressure between the intervention group and the control group is 3.00 mmHg. This shows that administering 2.4 grams of African leaf tea *(Vernonia amygdalina)* for 14 days, alongside antihypertensive drugs, is more effective than administering antihypertensive drugs alone in lowering diastolic blood pressure in women of childbearing age with hypertension.

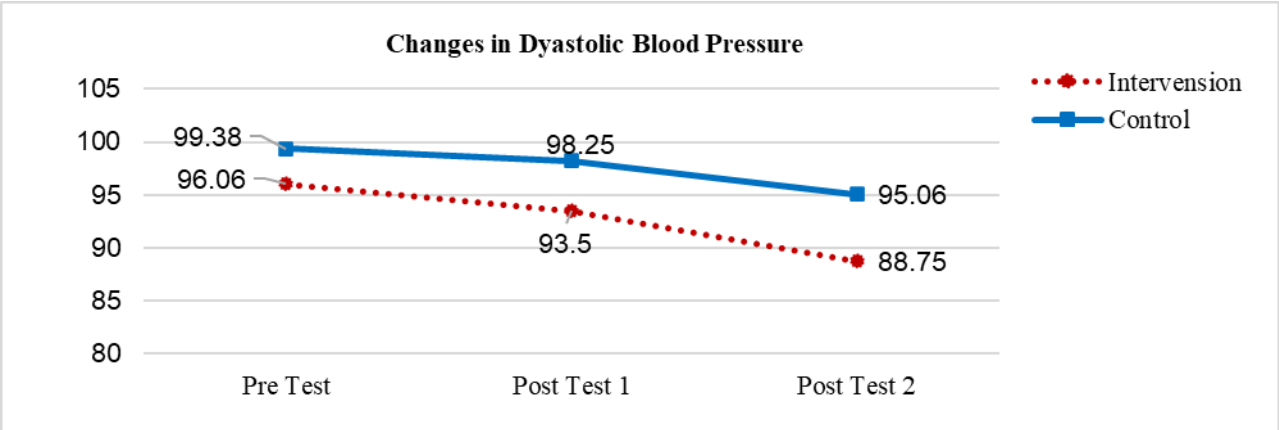

Figure 2. Changes in Diastolic Blood Pressure in the Intervention Group and Control Group

The results of the analysis in figure 2 show the average pretest diastolic blood pressure in the intervention group of 96.06 mmHg , which decreased after receiving 2.4 grams of African leaf tea (*Vernonia amygdalina*) for 14 days, with a difference of 7.31 mmHg between pre-test and post-test values, resulting in a post-test value of 88.75 mmHg. The analysis of the average diastolic blood pressure in the control group also showed a decrease, with a pre-test value of 99.38 mmHg and a post-test value of 95.06 mmHg, resulting in a difference of only 4.32 mmHg.

Table 3.
Hematocrit Levels in Intervention Group and Control Group Based on Measurement Time

Measurement Time	Intervention Group		Control Group	
	Mean Difference	*p value* [a]	Mean perbedaan	*Mean Difference*
Pre >< Post 1	1,18	0,000	1,75	0,000
Pre >< Post 2	2,68	0,000	3,62	0,000
Post 1 >< Post 2	1,50	0,000	1,87	0,001

[a] : *General Linear Model Repeated Measures*

Table 3 shows the average decrease in hematocrit levels pre-test and post-test, with a p-value of 0.000 in both the intervention group and the control group, indicating a significant difference in the average decrease in hematocrit levels before and after treatment. The average hematocrit levels from pretest to post-test in the intervention group showed a decrease of 3.50 mg/dL, while in the control group, there was only a decrease of 3.31 mg/dL. The difference in the decrease in hematocrit levels between the intervention group and the control group is 0.19 mg/dL.

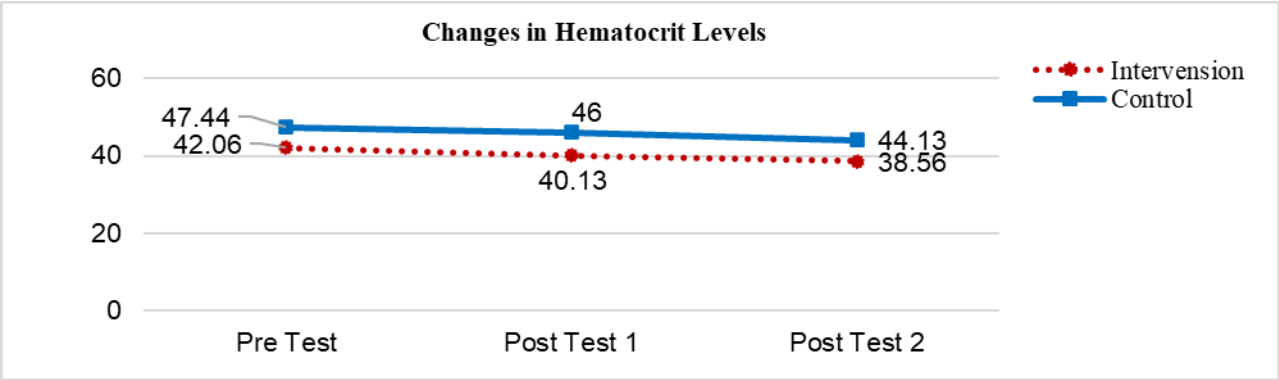

Figure 3. Changes in Hematocrit Levels in the Intervention Group and Control Group

The analysis of hematocrit levels in the intervention group showed an average pretest value of 42.06 mg/dL, which decreased by 3.50 mg/dL, to a post-test value of 38.56 mg/dL. In the control group, the average pretest value was 47.44 mg/dL, with a decrease of 3.31 mg/dL, resulting in a post-test value of 44.13 mg/dL.

DISCUSSION

Hypertension remains a significant global health challenge, particularly in women of childbearing age. Uncontrolled blood pressure can lead to severe complications, including cardiovascular disease and maternal mortality (Kementerian Kesehatan Republik Indonesia, 2021). While antihypertensive drugs are the standard treatment, non-pharmacological interventions, such as African leaf tea (*Vernonia amygdalina*), have gained attention for their complementary benefits. This study aimed to evaluate the efficacy of African leaf tea as an adjunct to antihypertensive medication in reducing systolic and diastolic blood pressure and hematocrit levels in women of childbearing age with hypertension. The findings revealed significant reductions in blood pressure and hematocrit levels among the intervention group that received African leaf tea alongside antihypertensive drugs compared to the control group. Systolic blood pressure in the intervention group decreased by 17.19 mmHg, compared to only 3.25 mmHg in the control group. Post-test measurements showed that systolic blood pressure averaged 141.25 mmHg in the intervention group, notably lower than the 154.88 mmHg recorded in the control group, with a p-value of 0.000 confirming statistical significance (Putri et al., 2022). Diastolic blood pressure also demonstrated substantial reductions, with a decrease of 7.31 mmHg in the intervention group compared to 4.32 mmHg in the control group.

Hematocrit levels also showed significant reductions in the intervention group, which experienced a decrease from 42.06 mg/dl to 38.56 mg/dl, averaging a reduction of 3.50 mg/dl. The control group exhibited a smaller decrease of 3.31 mg/dl, from 47.44 mg/dl to 44.13 mg/dl. These differences were statistically significant ($p = 0.000$). Elevated hematocrit levels have been associated with increased blood viscosity and cardiovascular risks, further highlighting the potential benefits of African leaf tea as part of hypertension management

(Jeong et al., 2021). The decline in hematocrit levels observed in this study is clinically significant, as elevated hematocrit levels are directly associated with increased blood viscosity, which can lead to heightened cardiovascular risk. High blood viscosity imposes additional workload on the heart, potentially exacerbating hypertension and contributing to cardiovascular complications. By reducing hematocrit levels, African leaf tea *(Vernonia amygdalina*) may offer protective cardiovascular effects beyond its role in lowering blood pressure. This finding aligns with research by Jeong et al. (2021), which emphasized the role of hematological parameters in influencing cardiovascular health outcomes, particularly among individuals with hypertension.

Hematocrit levels are a critical marker in the assessment of cardiovascular health. Elevated levels have been linked to hypertension due to the increased resistance posed by thicker blood to vascular flow (Dewi, 2020). Effective management of hematocrit levels, therefore, holds significant potential for mitigating cardiovascular risks. The reductions in hematocrit levels observed in the intervention group of this study underscore the potential of African leaf tea as a non-pharmacological approach for addressing such risks. The bioactive compounds in *Vernonia amygdalina*, such as flavonoids and alkaloids, may play a role in improving blood flow and vascular integrity, contributing to the observed hematological benefits. Comparative studies further highlight the clinical relevance of these findings. Research by Sileshi et al. (2021) revealed significant differences in hematological parameters between hypertensive and normotensive individuals, with hypertensive participants exhibiting higher hematocrit levels and increased cardiovascular risks. These observations underscore the importance of interventions that can effectively lower hematocrit levels, as demonstrated in this study. The consistent reduction in hematocrit levels among participants consuming African leaf tea reflects its potential to alleviate some of the hematological burdens associated with hypertension, further supporting its cardiovascular benefits. From a clinical perspective, addressing hematocrit levels as part of a comprehensive hypertension management plan could improve overall cardiovascular outcomes. The ability of African leaf tea to reduce both blood pressure and hematocrit levels positions it as a multifaceted intervention that targets key factors contributing to cardiovascular morbidity.

The effectiveness of *Vernonia amygdalina* as an antihypertensive agent can be attributed to its rich profile of bioactive compounds, including flavonoids, alkaloids, sesquiterpene lactones, saponins, tannins, phenolics, and triterpenoids. Among these, flavonoids play a critical role in promoting vasodilation by enhancing endothelial function and increasing nitric oxide bioavailability, which relaxes vascular smooth muscles and improves blood flow (Edo et al., 2023). Similarly, alkaloids work to clear vascular blockages, thus reducing vascular resistance and further supporting blood pressure regulation (Bestari, 2021; Dougnon et al., 2021). These mechanisms highlight the multidimensional benefits of *Vernonia amygdalina*, demonstrating its potential as a complementary treatment for hypertension. The antihypertensive properties of *Vernonia amygdalina* align with findings from studies on other plant-based interventions, such as *Hibiscus sabdariffa* and *Moringa oleifera*. Both plants are rich in antioxidants and have demonstrated vasodilatory properties similar to those of *Vernonia amygdalina. Hibiscus sabdariffa* has been shown to effectively reduce both systolic and diastolic blood pressure, while *Moringa oleifera* exhibits a strong ability to improve vascular function and reduce oxidative stress (Theofani & Susanto, 2023; Ummu, 2016). These comparisons underscore the broader applicability of bioactive plant compounds in cardiovascular health management.

Moreover, the findings align with evidence on the potential of dietary interventions in managing hypertension. For instance, Indriyani and Komala (2020) demonstrated that the

consumption of Labu Siam (chayote) significantly lowered blood pressure in hypertensive pregnant women, further highlighting the role of natural compounds in enhancing cardiovascular health outcomes. Similarly, Nugraheni et al. (2018) found that adequate mineral intake and optimal body mass index are critical for maintaining healthy blood pressure levels, particularly in women of childbearing age. This evidence underscores the importance of dietary management alongside pharmacological treatments in mitigating hypertension. The use of *Moringa oleifera* as a dietary supplement has also been shown to effectively lower blood pressure among hypertensive patients. Zebua et al. (2021) reported significant improvements in blood pressure among individuals consuming a decoction of *Moringa oleifera* leaves, attributing the benefits to the plant's high antioxidant and micronutrient content. These findings mirror the mechanisms observed with *Vernonia amygdalina*, further validating the effectiveness of bioactive plant-based therapies.

The current findings align with earlier research on the cardiovascular benefits of *Vernonia amygdalina.* Taiwo et al. (2010) demonstrated that aqueous extracts of this plant significantly improved cardiovascular parameters in animal models, reinforcing its potential for managing hypertension. Similarly, Igbokwe et al. (2020) reported that *Vernonia amygdalina* prevented electrolyte imbalances in salt-loaded rats, suggesting a stabilizing effect on blood pressure regulation. Furthermore, the anti-inflammatory and antioxidant properties of *Vernonia amygdalina* have been well documented, playing a significant role in reducing oxidative stress, a key contributor to hypertension (Airaodion et al., 2019). These properties highlight the plant's potential as a complementary intervention in hypertension treatment. In addition to the findings on *Vernonia amygdalina*, other plant-based interventions have also shown promise in blood pressure regulation and hematological health. Aprianti (2021) investigated the effects of dragon fruit juice on blood pressure in women of childbearing age, revealing a beneficial impact similar to that observed with *Vernonia amygdalina* tea. Meidiawati et al. (2018) examined the flavonoid content of *Vernonia amygdalina* leaves, underscoring the importance of bioactive compounds in promoting cardiovascular health. Furthermore, Purwanti and Aditya (2021) found that *Vernonia amygdalina* tea helped reduce cholesterol levels, which is closely linked to blood pressure regulation. In another study, Sari (2019) demonstrated that moringa leaf cookies could lower both blood pressure and blood lipids, further supporting the role of plant-based interventions in holistic hypertension management.

These findings collectively underscore the growing body of evidence suggesting the efficacy of herbal remedies, such as *Vernonia amygdalina*, in the management of hypertension. They also highlight the broader potential of integrating such plant-based solutions into comprehensive approaches for cardiovascular health.While the results are promising, discrepancies in the magnitude of blood pressure reductions between groups could stem from several factors. Variations in dosage standardization, individual adherence to dietary guidelines, and the short duration of the study may have influenced outcomes. Similar challenges have been observed in related studies exploring the efficacy of herbal interventions for hypertension (Ningrum et al., 2021).

The use of African leaf tea as an adjunct to antihypertensive drugs provides a non-pharmacological option for managing hypertension, particularly in resource-limited settings. This approach is supported by its accessibility, affordability, and minimal side effects, as reported in prior studies (Tihurua et al., 2023). The inclusion of such therapies can enhance patient adherence by offering alternative or complementary options to conventional medication. Moreover, the potential antioxidant and anti-inflammatory effects of *Vernonia amygdalina* may confer additional benefits, such as reducing the risk of comorbidities

associated with hypertension, including diabetes and cardiovascular disease (Huang et al., 2023). The findings of this study align with previous research and underscore the potential of *Vernonia amygdalina* as a non-pharmacological intervention for hypertension management. While limitations exist, the study provides a strong foundation for further exploration of plant-based therapies in hypertension management. By addressing current gaps in research, future studies can enhance the understanding and the application of *Vernonia amygdalina* in improving global cardiovascular health outcomes.

CONCLUSION

This study underscores the efficacy of African leaf tea (*Vernonia amygdalina*) as a complementary intervention to antihypertensive drugs in lowering blood pressure and hematocrit levels. The findings highlight its potential as a safe, non-pharmacological strategy for managing hypertension, supported by its bioactive compound-mediated vasodilatory effects. This study is not without limitations. The relatively small sample size and short intervention period may limit the generalizability of the findings. Additionally, dietary factors and lifestyle variations among participants, which were not fully controlled, could have influenced the outcomes. While the dosage of African leaf tea was standardized, variability in individual absorption and metabolism of its bioactive compounds may have affected the results. Future studies should address these factors by including larger, more diverse samples and examining the long-term effects of African leaf tea in different populations. To build upon these findings, future research could explore the mechanisms of action underlying the antihypertensive effects of African leaf tea, focusing on its interactions with various antihypertensive medications. Studies incorporating larger, more geographically diverse populations and extended intervention durations would enhance the robustness and applicability of the results. Additionally, investigations into the dose-response relationship and potential synergistic effects with other natural or pharmacological agents could provide deeper insights into optimizing its use in clinical settings.

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